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DIVISION OF CHEMISTRY

The Availability of Phosphoric Acid in Rock Phosphate

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COLLEGE STATION, BRAZOS COUNTY, TEXAS

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS

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CONTENTS.

	Page
Introduction	5
Relation to Soil Chemistry	5
Use of Rock Phosphate as a Fertilizer	5
Experimental Work	9
Phosphoric Acid Removed from Acid Phosphate	13
Acid Phosphate Compared with Manure	13
Acid Phosphate Compared with Rock Phosphate	13
Effect of Manure on Rock Phosphate	14
Details of Experiments	15
Acknowledgment	39
Summary and Conclusions	39

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THE AVAILABILITY OF PHOSPHORIC ACID IN ROCK PHOSPHATE.

By G. S. Fraps, Chemist.

Phosphate rock contains phosphoric acid as tri-calcium phosphate. The phosphoric acid is taken up very slowly by plants, and generally, before being used as a fertilizer, phosphate rock is treated with sulphuric acid for the purpose of rendering the phosphoric acid more available; that is to say, more easily taken up by plants. The resulting product is known as acid phosphate.

RELATION TO SOIL CHEMISTRY.

It was pointed out in Bulletin 126 of the Station, that the phosphoric acid, soluble in fifth-normal nitric acid, which we term the active phosphoric acid, is probably represented by calcium phosphate; while that not soluble is probably in the form of iron and aluminum phosphates. From the results of the pot experiments given in that bulletin, it appears that the needs of the soil for phosphate fertilizers are related to the quantity of active phosphoric acid present.

While the active phosphoric acid may be present in other forms than calcium phosphate, it seems probable that most of it is present in this form. The study of the availability of the phosphoric acid of rock phosphate should thus throw some light upon the active phosphoric acid of the soil. This was one of the objects of the experiments here reported.

It was likewise pointed out in Bulletin No. 126 that organic matter, carbonate of lime, and other soil substances, might affect the quantity of phosphoric acid taken up from the soil. Studies along this line have been presented in Bulletin No. 178, and the study of the effect of organic matter upon the availability of rock phosphate is reported in this bulletin.

USE OF ROCK PHOSPHATE AS A FERTILIZER.

The studies here reported have also a bearing upon the use of rock phosphate as a fertilizer. It has long been known that the phosphoric acid of rock phosphate has only a low availability, and for this reason it is generally treated with sulphuric acid, as stated above.

Of recent years, it has been claimed that decaying organic matter increases the availability of the phosphoric acid of rock phosphate, and its use in connection with green crops has been rather strenuously advocated in some States.

For example, Hopkins, in Illinois Soil Report No. 9, April, 1915, states that "The abundant information thus far secured shows positively that fine-ground natural rock phosphate can be used successfully

and very profitably, and clearly indicates that this material will be the most economical form of phosphorus to use in all ordinary systems of permanent, profitable soil improvement. The first application may well be one ton per acre, and subsequently about one-half ton per acre every four or five years should be applied, at least until the phosphorus content of the plowed soil reaches 2,000 pounds per acre, which may require a total application of from three to five or six tons per acre of raw phosphate containing 12½ per cent. of the element phosphorus."

Two thousand pounds of phosphorus per acre is equivalent to 0.23 per cent. phosphoric acid, which should supply the soil well with phosphoric acid. Since phosphate rock, finely ground, costs about $9.00 per ton in Texas (freight included), the application recommended would involve an investment of from $27.00 to $54.00 per acre. Such an application is, of course, practicable only by the man who owns the land having money to invest, and on land of high value. It is not practical on land of low value, with borrowed money which must be returned at the end of the crop season, or on land belonging to some one else who may reap the returns.

Field experiments with rock phosphate by the experiment stations have been carried out with smaller quantities than those recommended above, and the results are not always favorable to rock phosphate.

Mooers, in Tennessee Bulletin No. 90, 1910, makes the following statements:

"According to this table, without liming, acid phosphate ranks first, bone meal second, and phosphate rock third in profitableness of returns, whether the cowpeas be turned under for green manure or removed for hay, but any one of the three may be used with profit. Under liming, which is necessary in order to get remunerative crops of clover on these soils, and is, therefore, fundamental to their most successful management, acid phosphate is easily first, bone meal may be used with profit, but phosphate rock is liable to be used at a loss.

"There is a somewhat popular opinion, especially among those who are interested in the sale of phosphate rock, that the rock increases appreciably in effectiveness with the lapse of time after incorporation with the soil. A comparison of the last crops harvested throughout the series gives little ground for this opinion. A consideration of the per cent. of decrease in yield from the first to the last crop of wheat, for each phosphated and unphosphated plot where the cowpeas were turned under shows that the unphosphated plots, as an average of the first three series, declined most and that phosphate rock, bone meal, and acid phosphate followed in the order named.

"Another argument advanced in favor of phosphate rock is that its cheapness will permit the making of heavy applications, supplying an excess of phosphoric acid over that removed by the crops, so that there will be a 'permanent' increase in the soil supply. The results obtained here, however, demonstrate that under liming, which should be consid-

ered necessary, acid phosphate would without doubt be a more profitable material than phosphate rock."

Keitt, South Carolina Bulletin No. 178, 1914, as a result of several experiments, states:

"When applied alone or in combination with potash, the ground phosphate rock has proved the most profitable the last two years. However, when both nitrogen and potash were supplied, the results were in favor of the acid phosphate the last two years, as well as for the four-year period, in every case." Elsewhere he states (page 9) that the reason for the poorer results with the acid phosphate the last two years, is due to the depletion of the nitrogen or potash content of the soil, or both, caused by the heavier crops of the first two years."

Brooks, Massachusetts Bulletin No. 162, 1915, concludes that, in his Massachusetts experiments the natural rock phosphates have produced much smaller average increases in crops than those of other classes. He states further:

"Relative Profits on the Different Phosphates.—The results presented fully establish the facts of larger relative increases and in some instances superior quality of crops on the more soluble and available phosphates. Clearly, therefore, the use of such phosphates rather than the fine-ground natural rock phosphates is the part of wisdom, unless the cost of the latter is so much lower that they allow greater profit on their use than do the more soluble phosphates, in spite of the greater crop increases on the latter. The table gives the differences in value between the average annual crop increases and the average cost for the different classes of phosphates.

TABLE 1. MASSACHUSETTS.

Gain or Loss Per Acre in Crop Values Compared with Cost of Phosphate.

	Natural mineral phosphates.	Basic slag and bone meals.	Dissolved phosphates.
Cost of phosphates	$3.67	$3.70	$3.24
Corn, average three crops, 1899, 1913, 1914.			
Grain, average three crops, 1899, 1913, 1914	—0.79	6.02	7.47
Stover, average three crops, 1899, 1913, 1914	.95	2.72	1.95
Total, average three crops, 1899, 1913, 1914	$ .16	$8.74	$9.42
Hay, average two crops, 1906, 1907.			
Hay, average two crops, 1906, 1907	$3.19	$4.92	$6.03
Rowen, average two crops, 1906, 1907	—.79	.58	2.10
Total, average two crops, 1906, 1907	$2.40	$5.50	$8.13
Onions, average two crops, 1901, 1902 (sound)	—15.30	71.80	68.36
Cabbage, average two crops 1903, 1908	58.91	126.16	112.55
Oat hay, one crop, 1900	1.39	7.95	9.12
Hungarian hay, one crop, 1900	1.00	—1.33	—1.52
Total	2.39	6.62	7.60
Ensilage corn, one crop, 1904	—6.55	30.44	29.44
Soy beans, one crop, 1909.			
Beans, one crop, 1909	2.31	12.27	11.61
Straw, one crop, 1909	.87	2.38	2.33
Total, one crop, 1909	3.18	14.65	13.94

TABLE 1.—MASSACHUSETTS—Continued.

Gain or Loss per Acre in Crop Values Compared With Cost of Phosphate.

	Natural mineral phosphates.	Basic slag and bone meals.	Dissolved phosphates.
Potatoes, one crop, 1910.			
Merchantable	—6.42	9.84	16.14
Small	0.48	.50	.52
Total	—5.94	10.34	16.66
Oats and alfalfa, one crop, 1911	.48	9.76	9.36
Alfalfa, one crop, 1911	.83	2.20	.66
Total	1.31	11.96	10.02
Annual average	6.21	36.23	34.57

"The results shown in this table are overwhelmingly conclusive on the point under discussion. The values of the crop increases in all instances exceed the cost of phosphate many times more on the more soluble and available materials than on the natural rock phosphates. The latter afford, therefore, far lower profits on their use than the former.

"*Cumulative Effect.*—The advocates of the use of the rock phosphates may at this point urge that while such phosphates are at first less effective than the more soluble and quickly available materials they will ultimatelly fully equal the latter. This series of experiments has now continued eighteen years, and it would seem that this result should have been already realized. This has not been the case. The more soluble phosphates, bone meal and slag, still annually exceed the rock phosphates greatly in their effect on crop yield. Such excess, so far as can be judged, is still as great as at any earlier period."

Wiancko and Conner, Indiana Bulletin No. 187, 1916, conclude:

"In a general summary of all the experiments of the Station during thirteen years, in which eighty-two tests were made, it appears that:

"The per-acre net profit has been over six times as great from acid phosphate as from rock phosphate.

"The per-dollar invested profit has been over seven times as great from acid phosphate as from rock phosphate.

"The value of the crop increase per pound of phosphorus applied has been twenty-eight and one-third cents for the acid phosphate and three and one-half cents for the rock phosphate."

In the body of the bulletin they give the following:

"As a result of the eighty-two tests it may be said most emphatically that it pays to use acid phosphate on the average Indiana soil under average conditions. Raw rock phosphate has also shown a profit, but the profit is much smaller.

TABLE 2. INDIANA EXPERIMENTS.

Summary of All Experiments in Which Acid Phosphate and Raw Rock Phosphate Have Been Compared.

Crops.	Kind of Phosphate.	Yield. Bu.	Increase. Bu.	Phosphate, pounds.	Value of increase[1]	Cost of phosphates.	Profit or loss.
Corn	Acid phosphate	43.04	5.49	190.5	$2.95	$1.52	$1.43
36 tests.	Raw rock	42.20	4.65	532.0	2.52	1.86	.66
	None	37.55					
Wheat	Acid phosphate	15.28	4.31	190.5	4.63	1.52	3.11
33 tests.	Raw rock	12.88	1.91	532.0	2.12	1.86	.26
	None	10.97					
		Lbs.	Lbs.				
Legume hay	Acid phosphate	2,998	320	190.5	1.60	1.52	.08
9 tests.	Raw rock	2,773	95	532.0	.47	1.86	—1.39
	None	2,678					
		Bu.	Bu.				
Potatoes	Acid phosphate	112.0	29.4	500	14.70	4.00	10.70
4 tests.	Raw rock	94.2	11.6	1,000	5.80	3.50	2.30
	None	82.6					
Average of	Acid phosphate			205	$4.06	$1.64	$2.42
82 test.[2]	Raw rock			545	2.29	1.91	.38

[1]Value of increase includes value of corn stover and wheat straw.
[2]Average length of time tests have been running, 3.47 years.

EFFECT OF ORGANIC MATTER ON AVAILABILITY.

Hartwell, in Rhode Island Bulletin No. 151, reviews the experiments bearing upon the effect of decaying organic matter upon the availability of rock phosphate, and presents some pot experiments of his own. He concludes that in his experiments the cow manure had little or no effect upon the availability of the rock phosphate, whether applied at the time of planting or mixed and allowed to ferment several months. He concludes from his review of the literature that "the experimental evidence so far presented is not sufficient to prove that decaying organic matter exerts any material effect upon the availability of the phosphoric acid of rock phosphate. Although it is not desired to conclude as a result of the present pot experiment that manure may not, under some circumstances, increase the availability of floats, it appears, on the other hand, that further experimental evidence is necessary before it can be generally taught that the good results which may follow the application of floats and manure or even other organic matter, are due in any considerable degree to the action of one upon the other."

In Bulletin No. 178 of the Texas Station, it was shown that organic matter may increase to a small extent the quantity of phosphoric acid taken up from the soil in pot experiments.

EXPERIMENTAL WORK.

In the pot work here presented, the quantity of phosphoric acid used in acid phosphate was small in order that it should not, if possible, exceed the requirements of the plants. If an excess of phosphoric acid is used, the results would be more favorable to the less available phosphates. Details of the experiments are presented on subsequent pages.

Table 3 shows the percentages of added phosphoric acid recovered

in the various experiments. Thus, of the 0.2 gram available phosphoric acid added to soil 844, Series 4, 50.5 per cent. was recovered by the first crop, and 8.5 per cent. by the second. The figures refer to phosphoric acid and do not represent relative weights of the crops.

TABLE 3. PERCENTAGE OF ADDED PHOSPHORIC ACID RECOVERED.

Lab. No.			AC	ACE or MAC	R or P	RE or MR	M or EX.
844	First crop, Series 4—	Rice	50.5	.....	8.8	.....	.....
	Second crop,	Rice	8.5	.....	0	.....	.....
		Total	59.0	.....	8.8	.....	.....
		Per crop	29.5	.....	4.4	.....	.....
852	First crop, Series 4—	Rice	54.9	.....	15.2	.....	.....
	Second crop,	Rice	19.4	.....	8.5	.....	.....
		Total	74.3	.....	23.8	.....	.....
		Per crop	37.2	.....	11.9	.....	.....
844	First crop, Series 4—	Corn	56.6	.....	4.6	.....	.....
852	First crop, Series 4—	Corn	61.8	.....	17.6	.....	.....
844	First crop, Series 11—	Rice	10.3	0	0	0	47
	Second crop,	Rice	20.5	0	1.4	0	103
	Third crop,	Rice	4.2	2.3	0	0	7
		Total	35.0	2.3	1.4	0	157
		Per crop	11.7	0.8	0.5	0	52
852	First crop, Series 11—	Rice	48.5	35.8	3.0	5	51
	Second crop,	Rice	0	2.0	8.3	0	63
	Third crop,	Rice	1.4	9.5	6.6	1.5	39
		Total	49.9	47.3	17.9	6.5	153
		Per crop	16.6	15.8	6.0	2.2	51
1956	First crop, Series 44—	Mu tard, 1909	8.8	0	5.7	0	12.6
	Second crop,	Corn, 1910	43.5	11.0	12.6	0	32.1
	Third crop,	Sorghum, 1910	20.8	14.3	0.6	0.7	19.4
		Total	73.1	25.3	18.9	0.7	64.1
		Per crop	24.7	8.4	6.3	0.2	21.4
	First crop,	Mustard, 1911	11.0	2.5	0	0	8.7
	Second crop,	Corn, 1911	22.3	29.0	2.5	0	29.6
	Third crop,	Sorghum, 1911	4.2	13.5	0.3	5.3	23.8
		Total	37.5	45.0	2.8	5.3	62.1
		Per crop	12.5	15.0	0.9	1.8	20.7
2377	First crop, Series 44—	Mustard, 1910	0.8	1.7	0.9	0.6	2.8
	Second crop,	Corn, 1910	20.7	26.9	0	0.1	5.1
	Third crop,	Sorghum, 1910	10.1	6.7	0.2	0	8.7
		Total	31.6	35.3	1.1	0.7	16.6
		Per crop	10.5	11.8	.4	0.2	5.5
	First crop,	Mustard, 1911	8.3	7.8	0.6	2.3	6.6
	Second crop	Corn, 1911	21.5	19.2	0	0	42.1
	Third crop,	Sorghum, 1911	16.8	0	0	0	27.2
		Total	46.6	27.0	0.6	2.3	75.9
		Per crop	15.5	9.0	0.2	0.8	25.3
2378	First crop, series 44,—	Mustard, 1910	1.0	9.9	0	0	1.4
	Second crop,	Corn, 1910	30.3	13.2	0	0	12.7
	Third crop,	Sorghum, 1910	6.4	9.3	0	0	7.5
		Total	37.7	32.4	0	0	21.6
		Per crop	12.6	10.8	0	0	7.2
	First crop,	Mustard 1911	.....	.....	.....	.....	.....
	Second crop,	Corn, 1911	16.3	17.1	7.0	1.9	31.6
	Third crop,	Sorghum, 1911	15.6	11.7	7.4	4.6	22.3
		Total	31.9	28.8	14.4	6.5	53.9
		Per crop	10.6	9.6	4.8	2.2	18.

TABLE 3—Continued. PERCENTAGE OF ADDED PHOSPHORIC ACID RECOVERED.

Lab. No.			AC	ACE or MAC	R or P	RE or MR	M or EX.
3333	First crop, Series 45—	Sorghum, 1910..	16.5	21.4	0	5.7	0
	Second crop,	Mustard, 1911..	.....	.....	.....	.....	.....
	Third crop,	Corn, 1911.....	6.0	3.1	1.7	5.1	6.0
		Total.....	22.5	24.5	1.7	10.8	6.0
		Per crop....	7.5	8.2	.6	3.6	2.0
3653	First crop, Series 45—	Sorghum, 1910..	44.4	27.3	11.3	11.1	13.8
	Second crop,	Mustard, 1911..	.....	.....	.....	.....	.....
	Third crop,	Corn, 1911.....	10.9	8.7	3.1	7.3	36.7
		Total.....	55.3	36.0	14.4	18.4	50.5
		Per crop....	18.4	12.0	4.8	6.1	16.8
3652	First crop, Series 45—	Sorghum, 1910..	49.8	42.8	5.8	7.1	1.0
	Second crop	Mustard, 1911..	.....	.....	.....	.....	.....
	Third crop,	Corn, 1911.....	4.9	7.2	0	6.1	48.2
		Total.....	54.7	50.0	5.8	13.2	49.2
		Per crop....	18.2	16.7	1.9	4.4	16.4
	First crop,	Corn, 1912.....	21.1	28.9	0	9.1	41.9
3654	First crop, Series 46—	Corn, 1911.....	31.4	21.6	0	1.5	0
	Second crop,	Sorghum, 1911..	12.3	6.6	5.3	6.0	6.6
		Total.....	43.7	28.2	5.3	7.5	6.6
		Per crop....	21.9	14.1	2.7	3.8	3.3
3634	First crop, Series 46—	Corn, 1911.....	.....	15.6	0	.....	1.0
	Second crop,	Sorghum, 1911..	.....	22.5	0	.....	7.7
		Total.....	.....	38.1	0	.....	8.7
		Per crop....	.....	19.1	0	.....	4.4

Lab. No			AC	AE or MAC	R or P	RE or MR	M or Ex.
3656	First crop, Series 46—	Corn, 1911.....	21.2	36.9	5.8	6.8	3.6
	Second crop,	Sorghum, 1911..	7.3	7.7	6.7	6.2	8.8
		Total.....	28.5	44.6	12.5	13.0	12.4
		Per crop....	14.3	22.3	6.3	6.5	6.2
3975	First crop, Series 46—	Corn, 1911.....	32.9	22.3	13.4	2.3	0
	Second crop,	Sorghum, 1911..	20.0	19.2	9.4	3.8	12.4
		Total.....	52.9	41.5	22.8	6.1	12.4
		Per crop....	26.5	20.8	11.4	3.1	6.2
2409	First crop, Series 46—	Corn, 1911.....	10.2	15.4	7.1	8.5	0
	Second crop,	Sorghum, 1911..	9.8	14.2	6.4	1.8	30.0
		Total.....	20.0	29.6	13.5	10.3	30.0
		Per crop....	10.0	14.8	6.8	5.2	15.0
2829	First crop, Series 46—	Corn, 1911.....	.....	0	.....	2.4	7.4
	Second crop,	Sorghum, 1911..	.....	9.2	.....	7.1	0
		Total.....	.....	9.2	.....	9.5	7.4
		Per crop....	.....	4.6	.....	4.8	3.7

TABLE 3—Continued. PERCENTAGE OF ADDED PHOSPHORIC ACID RECOVERED

Lab. No.		Ac E	R,E	M	R2 E	ER3
4582	First crop, Series 47—Corn, 1911.....	22.6	3.6	13.1	0	4.5
	Second crop, Sorghum, 1911..	0	1.8	14.8	2.8	0.3
	Total.....	22.6	5.4	27.9	2.8	4.8
	Per crop....	11.3	2.7	14.0	1.4	2.4
4586	First crop, Series 47—Corn, 1911.....	13.2	2.0	24.1	6.4	6.4
	Second crop, Sorghum, 1911..	16.5	11.7	6.3	11.8	12.2
	Total.....	29.7	13.7	30.4	18.2	18.6
	Per crop....	14.9	6.9	15.2	9.1	9.3
4587	First crop, Series 47—Corn, 1911.....	15.6	1.7	23.7	0	2.6
	Second crop, Sorghum, 1911..	4.6	0	17.1	1.0	1.6
	Total.....	20.2	1.7	40.8	1.0	4.2
	Per crop....	10.1	.9	20.4	.5	2.1

Lab No.		Ac	Ac E	R	R,E	M
2831	First crop, Series 46—Corn, 1911.....	14.8	29.5	0	6.7	0
	Second crop, Sorghum, 1911..	13.2	16.7	3.6	1.8	14.3
	Total.....	28.0	46.2	3.6	8.5	14.3
	Per crop....	14.0	23.1	1.8	4.3	7.2
2342	First crop, Series 48—Corn, 1913.....	15.2	29.0	.....	5.8	12.6
	Second crop, Sorghum, 1913..	19.5	8.6	.....	3.8	20.8
	Third crop, Corn 1914.....	0.5	11.3	.....	7.9	4.5
	Fourth crop, Sorghum, 1914..	4.3	0	.....	2.9	0
	Total.....	39.5	48.9	.....	20.4	37.9
	Per crop....	9.9	12.2	.....	5.1	9.5
2348	First crop, Series 48—Corn, 1913.....	33.7	36.3	.....	12.4	18.2
	Second crop, Sorghum, 1913..	12.0	11.1	.....	9.5	11.1
	Third crop, Corn, 1914.....	8.9	7.1	.....	4.1	3.2
	Fourth crop, Sorghum, 1914..	10.3	0	.....	0	10.2
	Total.....	64.9	54.5	.....	26.0	42.7
	Per crop....	16.2	13.6	.....	6.5	10.7

Lab. No.		AC	ACE	R	RE	E
5095	First crop Series 48—Corn, 1913.....	36.1	56.8	.....	29.7	39.2
	Second crop, Sorghum, 1913..	13.0	0	.....	1.9	19.1
	Third crop, Corn, 1914.....	10.1	9.4	.....	8.7	4.6
	Fourth crop Sorghum, 1914..	10.1	0	.....	0	7.5
	Total.....	69.3	66.2	.....	40.3	70.4
	Per crop....	17.3	16.6	.....	10.1	17.6
5701	First crop, Series 48—Corn, 1913.....	41.4	41.0	3.1	8.3	16.4
	Second crop, Sorghum, 1913..	7.2	15.5	2.8	2.2	15.3
	Third crop, Corn, 1914.....	1.8	0	2.9	2.5	1.4
	Fourth crop, Sorghum, 1914..	7.1	0	6.9	0	8.2
	Total.....	57.5	56.5	15.7	13.0	41.3
	Per crop....	14.4	14.1	3.9	3.3	10.3
6885	First crop, Series 48—Corn, 1913.....	48.4	26.7	11.2	0	38.5
	Second crop, Sorghum, 1913..	15.0	21.1	5.5	16.2	6.5
	Third crop, Corn, 1914.....	6.7	4.7	6.6	12.4	5.2
	Fourth crop, Sorghum, 1914..	3.2	0	6.2	6.2	4.6
	Total.....	73.3	52.5	29.5	34.8	54.8
	Per crop....	18.3	13.1	7.4	8.7	13.7

Phosphoric Acid Removed from Acid Phosphate.—The percentages of phosphoric acid recovered from acid phosphate vary from 20.0 to 74.3 per cent. The average recovery of phosphoric acid of acid phosphate for all crops, in 25 experiments, is 48.2, with a standard deviation for the individual tests of 0 ± 14.4 and a standard deviation from the average of ± 2.2. It is clear that one may reasonably count on an average recovery of 50 per cent of the phosphoric acid added in acid phosphate.

When conditions are favorable, the greatest quantity of the phosphoric acid of acid phosphate is taken up by the first crop. This may vary from 40 to 60 per cent of the total. The average quantity of phosphoric acid taken by the first crop is 30.6, compared with the average of all crops (22 tests) of 47.3. Thus two-thirds is, on an average, taken up by the first crop.

Acid Phosphate Compared with Manure.—The average quality of phosphoric removed from acid phosphate in 22 tests (some with manure), is 37.9 per cent., compared with 39.2 for the phosphoric acid from manure alone. We have either to conclude that the phosphoric acid of the manure or excrement is highly available to plants, or that the manure assisted in the assimilation of soil phosphates by plants. In Bulletin No. 178 we presented evidence to show that manure or organic matter, to a slight extent, makes phosphoric acid of the crop more available.

When acid phosphate alone is compared with acid phosphate and manure (18 tests) we find a recovery of 39.1 for the acid phosphate, 34.1 for the acid phosphate with manure after correction for the phosphoric acid removed from the manure. We ascribe this decrease in assimilation of the phosphoric acid of acid phosphate to the fact that the supply of phosphoric acid in some cases exceeded the needs of the crop, and so the crop removed less. In 11 cases there are decreases, and in 7 there are increases of the phosphoric acid removed from the acid phosphate, when manure is present.

Acid Phosphate Compared with Rock Phosphate.—An examination of the table shows decided variations in the comparative recovery of phosphoric acid from rock phosphate. For example, 35.0 per cent. of the phosphoric acid of acid phosphate is recovered by three crops of rice on soil 844, and only 1.4 per cent. from rock phosphate; while from soil 852 with rice likewise, the recovery from acid phosphate is 74.3 and from rock phosphate 23.8. In the one case, the rock phosphate is 20 times as available. There is evidently a decided difference in the availability in different soils.

The average recovery for all experiments where a comparison is made (21) is 43.9 per cent. for acid phosphate with a standard deviation of ± 15.7 for individuals and of ± 2.3 for the average; and 9.1 per cent. for rock phosphate, with a standard deviation for individuals of ± 7.7 and the average of ± 1.1.

Thus the phosphoric acid in rock phosphate in these experiments has, on an average, 21 per cent. of the value of acid phosphate. As stated

above, there are some soils in which the rock phosphate apparently has no value, and others where its value is high. There are 8 of the 21 tests in which the availability of the rock phosphate is 25 per cent. or more than that of the acid phosphate.

Whether the relative values above given would apply to field conditions, and to larger applications of rock phosphate, requires further study. It does not follow, for example, that the application of five pounds of phosphoric acid in rock phosphate will produce the same effect as one pound phosphoric acid in acid phosphate for the reason that rock phosphate is only slightly soluble in the soil moisture and five times the application may really only increase slightly the amount of phosphoric acid presented to the roots. There may be a point at which increased applications of rock phosphate may have no effect upon the size of the crop, as it is possible that the phosphoric acid of rock phosphate may not enter the plant rapidly enough to produce the corresponding growth. That is to say, the rock phosphate is only slightly soluble and may not increase the concentration of the soil moisture sufficiently to produce rapid growth, and further additions of rock phosphate might not increase the concentration of the phosphoric acid in the soil moisture beyond a certain point.

Assuming acid phosphate containing 16 per cent. available phosphoric acid to cost $19.20 per ton, what would be the value of rock phosphate containing 28 per cent. phosphoric acid, if the phosphoric acid has one-fifth the value of that of acid phosphate? One-fifth of 28 is 5.6 per cent.; so that the rock phosphate would be equivalent to acid phosphate containing 5.6 per cent. available phosphoric acid. At six cents per pound, which would be the cost of available phosphoric acid in 16 per cent. acid phosphate, at $19.20 per ton, the rock phosphate would have a valuation of $6.72 per ton. Thus acid phosphate, on the basis of the above assumptions would give a larger immediate profit than rock phosphate at $7.00 a ton. The phosphoric acid of the rock phosphate would, of course, remain in the soil until utilized by the plants.

These comparisons are made on the basis of several crops grown with the acid phosphate and the rock phosphate. If the first crops only are considered, the showing is still more favorable to acid phosphate. As stated above, the first crops removed 30.6 per cent. phosphoric acid from acid phosphate, while all the crops removed 47.3 per cent. With rock phosphate and manure (23), the first crop removed 5.3 per cent., and all crops 11.9 per cent. Thus the phosphoric acid of the acid phosphate had nearly six times the value of the phosphoric acid of the rock phosphate for the first crops.

We have as yet not been able to trace any connection between the chemical composition of the soils and the differences in the availability of the phosphoric acid of rock phosphate.

Effect of Manure on Rock Phosphate.—In 19 tests, rock phosphate alone averaged a recovery of 9.6 per cent. phosphoric acid, with a standard deviation of ± 8.6 for individuals and ± 1.3 for the average;

hile rock phosphate with manure averaged 8.7 per cent., with a tandard deviation of ±8.6 for individuals and ±1.2 for the average, orrection being made for the phosphoric acid removed from the ma- ure alone.

The addition of manure apparently had no effect upon the recovery f the phosphoric acid of the rock phosphate. This confirms the con- lusions of Hartwell, although it is apparently not in accord with the act that manure or organic matter increases the phosphoric acid re- ioved by crops from some soils. However, there are some soils in hich the manure apparently increases the removal of phosphoric acid rom rock phosphate, and then again, the phosphoric acid of soils is vidently not present as rock phosphate for the most part.

In 32 tests, acid phosphate with manure averages 32.2 per cent. re- overy, compared with 10.2 per cent. for rock phosphate and manure, orrection being made for the phosphoric acid removed from the manure lone. These results show a slightly better recovery of the phosphoric cid of rock phosphate, and a decidedly poorer recovery of that from cid phosphate, over those previously given. As already stated, it is robable that in some of the tests the phosphoric acid supplied by the cid phosphate and manure exceeded the needs of the plants.

We conclude that in these pot experiments, manure had, on an verage, little or no effect upon the assimilation of phosphoric acid of ock phosphate by plants.

DETAILS OF EXPERIMENTS.

Tables 4 to 10, inclusive, contain the detailed results of the work.

Series 4. Soils 852 and 844, with 5 kg. soil. Additions: 2 gms. otassium sulphate, 2 gms. ammonium nitrate; 0.2 gm. water-soluble nd reverted phosphoric acid in acid phosphate, No. 600 (K. C.); .2 gm. phosphoric acid in phosphate rock No. 837. Planted (A) 5 rains corn weighing 2.0-2.1 gms; (B) 10 grains rice weighing 0.34- .36 gm. First crop, 1907. Second crop, rice planted, April 10, 1908, arvested August 18, 1908, did very poorly, perhaps flooded too soon. Addition of 1 gm. each ammonium nitrate and sulphate of potash were nade before planting, and ½ gm. each on June 1.

Series 11. Soils 844 and 852 with 5 kg. soil. Additions: 1 gm. ach sulphate of potash and nitrate of soda; 5 gms. excrement No. 917 (M), containing .0415 gm. P_2O_5; 0.2 gms. available phosphoric acid n acid phosphate No. 2480; 0.2 gm. phosphoric acid in phosphate rocks No. 857. Planted rice March 23, 1909, flooded May 4, harvested September 3, 1909.

Second crop rice; additions 1 gm. each sulphate of potash and am- monium nitrate; 5 gms. excrement No. 917; 0.10 gm. available phos- phoric acid in acid phosphate No. 3194; 0.15 gm. phosphoric acid in phosphate rock No. 729. Planted July 12, 1910, flooded August 5, harvested November 22, 1910.

Third crop, rice; additions, 1 gm. each ammonium nitrate and sulphate of potash. Planted April 7, harvested August 26, 1911.

Series 44. 1909. Soils 1956, 2377, 2378, with 10 kg. soil. Additions; 2 gms. each sodium nitrate and potassium sulphate; 0.15 gm. available phosphoric acid in acid phosphate No. 2671 (A. C.); 0.30 gm. total phosphoric acid in phosphate rock No. 729 (R), containing .0132 gm. phosphoric acid; 15 gms. excrement No. 904 (Ex.).

First crop; mustard, planted December 1, 1909, killed by freeze and harvested February 21, 1910.

Second crop; corn: planted April 5, harvested June 17, 1910. Additions of 2 gms. each sulphate of potash and nitrate of soda.

Third crop; sorghum: added 1 gm. each potassium chloride and ammonium nitrate. Planted June 18, harvested September 13, 1910.

Fourth crop; mustard: added 1 gm. each ammonium nitrate and sulphate of potash; 15 gms. excrement No. 3222 (Ex.), containing .1125 gm. phosphoric acid; 0.15 gm. available phosphoric acid in acid phosphate No. 2671; 0.30 gm. total phosphoric acid in phosphate rock No. 729. Planted mustard October 17, 1910, harvested January 4, 1911.

Fifth crop; corn: added 1 gm. each ammonium nitrate and potassium sulphate. Planted March 23, harvested June 2, 1911.

Sixth crop; corn: added 1 gm. each ammonium nitrate and sulphate of potash. Planted June 26, harvested September 4, 1911.

Seventh crop; corn (1956 on 17): added 1 gm. each sulphate of potash and ammonium nitrate. Planted April 22, harvested June 25, 1912.

TABLE 4. CROPS IN SERIES 4.

Lab. No.		Crop Gm.	Per cent P_2O_5	Gm. P_2O_5	Average.	Gain over 0	Per cent recovered.
844	First crop, rice, 1907, series 4						
	1-O	4.9	0.38	.0186	.0226	.....	.....
	2-O	8.6	0.31	.0266	.....	.....	.....
	3-AC	33.8	0.33	.1116	.1236	.1010	50.5
	4-AC	48.5	0.28	.1357	.....	.....	.....
	5-R	8.2	0.40	.0328	.0403	.0177	8.8
	6-R	15.4	0.31	.0477	.....	.....	.....
	Second crop rice, 1908.						
	1-O	1.2	0.25	.0030	.0030	.....	.....
	2-O	1.1	0.26	.0029	.....	.....	.....
	3-AC	7.6	0.35	.0266	.0201	.0171	8.5
	4-AC	3.4	0.40	.0136	.....	.....	.....
	5-R	0.4	0.37	.0014	.0031	.0001	0
	6-R	2.4	0.21	.0048	.....	.....	.....

TABLE 4—Continued. CROPS IN SERIES 4.

Lab. No.		Crop Gm.	Grain.	Per cent P_2O_5	Gm. P_2O_5	Aver-age.	Gain over 0	Per cent removed
852	First crop, rice, 1907, Series 4.							
	1-O	10.9	.....	0.29	.0229	.0263	.....	.....
	2-O	13.5	.....	0.22	.0297	.....	.....	.....
	3-AC	53.2	.....	0.26	.1380	.1362	.1099	54.9
	4-AC	54.1	.....	0.23	.1244	.....	.....	.....
	5-R	27.3	.....	0.18	.0491	.0568	.0305	15.3
	6-R	30.7	.....	0.21	.0644	.....	.....	.....
	Second crop, rice, 1908.	Straw Gm.	Grain Gm.					
	1-O	13.5	0	0.21	.0277	.0198	.....	.....
	2-O	5.4	0	0.22	.0119	.....	.....	.....
	3-AC	11.6	0	0.40	.0458	.0585	.0387	19.4
	4-AC	20.9	5.9	0.34	.0711	.....	.....	.....
	5-R	15.2	0.4	0.19	.0376	.0367	.0169	8.5
	6-R	13.1	1.0	0.27	.0359	.....	.....	.....

Lab. No.		Crop Gm.	Per cent P_2O_5	Gm. P_2O_5	Aver-age.	Gain over 0	Per cent removed.
	First crop corn, 1907, Series 4.						
844	1-O	8.8	0.26	.0228	.0212	.....	.....
	2-O	7.3	0.27	.0197	.....	.....	.....
	3-AC	56.6	0.25	.1415	.1345	.1133	56.6
	4-AC	58.0	0.22	.1276	.....	.....	.....
	5-R	9.3	0.28	.0260	.0304	.0092	4.6
	6-R	13.9	0.25	.0348	.....	.....	.....
852	1-O	10.4	0.21	.0218	.0172	.....	.....
	2-O	5.7	0.22	.0125	.....	.....	.....
	3-AC	58.2	0.25	.1455	.1408	.1236	61.8
	4-AC	52.3	0.26	.1360	.....	.....	.....
	5-R	22.9	0.23	.0527	.0525	.0353	17.6
	6-R	22.8	0.23	.0524	.....	.....	.....

TABLE 5. CROPS IN SERIES 11.

Lab. No.		Additions.	Rice heads.	1909 Rice Gms.	Per cent P_2O_5	Gm. P_2O_5	Gain over O	Gain over E	Per cent recovered.
844	First crop, Series 11, Rice (1909).								
	1-O	KN	1.3	14.6	0.17	.0248			
	2-R—0.2 gm. P_2O_5	KNR	0.5	9.4	0.20	.0188	0		0
	3-AC—0.2 gm. P_2O_5	KNAC	0.2	16.8	0.27	.0454	.0206		10.3
	4-M—5 gm. No. 917—.0415 gm. P_2O_5	KNM	3.0	18.2		.0445	.0197		47.0
	5-MR	KNMR	1.1	10.3	0.25	.0257		0	0
	6-MAC	KNMAC	0	17.2	0.25	.0430		0	0
	Second crio (1910).								
	1-O	KN	0	1.8	.16	.0029			
	2-R	KNR	0	4.3	.18	.0077	.0048		1.4
	3-AC	KNAC	4.2	19.2	.28	.0643	.0614		20.5
	4-M 5 gm	KNM	10.0	31.3	.21	.0880	.0851		103.
	5-MR	KNMR	2.0	14.6	.33	.0548		0	0
	6-MAC	KNMAC	5.8	19.8	.37	.0947		.0067	2.2
	Third crop (1911).								
	1-O	KN	0.3	4.5	.35	.0166			
	2-R	KN	0.3	6.1	.24	.0156	0		0
	3-AC	KN	1.5	9.7	.35	.0392	.0126		4.2
	4-M	KN	1.2	8.7	.25	.0226	.0060		.7
	5-MR	KN	0.4	4.1	.36	.0160		0	0
	6-MAC	KN	1.5	7.3	.33	.0294		.0068	2.3

Calculations on second and third crops are based on 3.5 gm. P_2O_5 from R and O, 3 gm. from acid phosphate.

TABLE 5—Continued. CROPS IN SERIES 11.

Lab. No.		1909 Rice Gms.	Rice heads.	Per cent P_2O_5 straw.	Per cent P_2O_5 heads.	Gms. P_2O_5	Gain over O.	Gain over E.	Per cent recovered.
	First crop, Series 11.								
852	1-O	27.1	5.0	.08	0.41	.0382			
	2-R	27.6	2.3	.16	0.48	.0441	.0059		3.
	3-AC	43.4	6.1	.28	0.69	.1352	.0970		48.5
	4-M 5 gms	28.8	5.3	.12	0.54	.0596	.0214		51.0
	5-MR	33.5	9.1	.11	0.48	.0685		.0089	5.0
	6-MAC	42.8	5.6	.26	0.54	.1311		.0715	35.8
	Second crop (1910).								
	1-O	11.3	0.5	.18		.0212			
	2-R	14.2	1.1	.26		.0402	.0290		8.3
	3-AC	7.0	0.3	.26		.0190	0		0
	4-M	20.1	2.3	.33		.0735	.0523		6.3
	5-MR	13.8	2.2	.29		.0464		0	0
	6-MAC	21.8	2.3	.33		.0803		.0058	2.0
	Third crop (1911).								
	1-O	0.8	0	.12		.0001			
	2-R	7.1	0.3	.32		.0231	.0230		6.6
	3-AC	1.7	0	.25		.0043	.0042		1.4
	4-M	9.3	2.9	.26		.0321	.0320		39.0
	6-MR	10.5	1.4	.31		.0372		.0051	1.5
	7-MAC	11.0	1.6	.40		.0507		.0286	9.5

TABLE 6. CROPS IN SERIES 44.

Lab. No.		Mustard 1909.	Per cent P_2O_5	Gms. P_2O_5	Aver-age.	Gain over O.	Gain over E.	Per cent recov-ered.
1956	1-KN	.5	.51	.0026	.0033			
	2-KN	1.0	.41	.0041				
	3-KNAC	4.2	.42	.0176	.0135	.0132		8.8
	4-KNAC	2.0	.47	.0094				
	5-KNP (hos)	3.5	.83	.0290	.0204	.0171		5.7
	6-KNP (hos)	2.0	.59	.0118				
	7-KNEX	4.0	.61	.0244	.0300	.0167		12.6
	8-KNEX	5.4	.65	.0351				
	9-KNACEX	4.3	.72	.0310	.0303		.0003	0
	10-KNACEX	3.5	.85	.0297				
	11-KNPEX	4.2	.71	.0298	.0244		.0000	0
	12-KNPEX	2.7	.73	.0197				

Lab. No.		Corn 1910.	Per cent P_2O_5	Gms. P_2O_5	Aver-age.	Gain over O.	Gain over E.	Per cent Recov-ered.
	Second crop, Series 44							
1956	1-O	25.5	.28	.0714	.0965			
	2-O	52.5	.24	.1216				
	3-AC	55.0	.26	.1430	.1618	.0653		43.5
	4-AC	64.5	.28	.1806				
	5-P	51.5	.27	.1390	.1343	.0378		12.6
	6-P	48.0	.27	.1296				
	7-Ex	53.0	.28	.1484	.1390	.0425		32.1
	8-Ex	54.0	.24	.1296				
	9-AcEx	51.0	.30	.1530	.1555		.0165	11.0
	10-ACEx	58.5	.27	.1579				
	11-PEx	61.2	.22	.1346	.1379		0	0
	12-PEx	56.5	.25	.1412				

Lab. No.		Sorghum 1910.	Per cent P_2O_5	Gms. P_2O_5	Aver-age.	Gain over O.	Gain over E	Per cent recov-ered
	Third crop, Series 44.							
1956	1-O	56.9	.28	.1593	.0961			
	2-O	14.9	.22	.0328				
	3-AC	56.0	.23	.1288	.1273	.0312		20.8
	4-AC	54.7	.23	.1258				
	5-P	49.2	.18	.0885	.0978	.0017		0.6
	6-P	53.5	.20	.1070				
	7-Ex	60.1	.21	.1262	.1218	.0257		19.4
	8-Ex	58.7	.20	.1174				
	9-ACEx	61.4	.24	.1474	.1433		.0215	14.3
	10-AcEx	55.7	.25	.1392				
	11-PEx	57.3	.21	.1203	.1239		.0021	0.7
	12-PEx	55.4	.23	.1274				

Lab. No.		Mustard 1909.	Per cent P_2O_5	Gms. P_2O_5	Aver-age.	Gain over O.	Gain over E.	Per cent recov-ered.
	Fourth crop, Series 44							
1956	1-O	2.7	.50	.0135	.0260			
	2-O	7.7	.50	.0385				
	3-AC*	7.4	.50	.0370	.0425	.0165		11.0
	4-AC	9.6	.50	.0480				
	5-P	1.5	.50	.0075	.0100	0		0
	6-P	2.5	.50	.0125				
	7-Ex	7.5	.50	.0375	.0358	.0098		8.7
	8-Ex	6.8	.50	.0340				
	9-ACEx	6.6	.50	.0330	.0395		.0037	2.5
	10-ACEx	9.2	.50	.0460				
	11-PEx	4.2	.50	.0210	.0255			0
	12 PEx	6.0	.50	.0300				

*New additions of P, Ex, and AC, Ex—.1125 gm. P_2O_5 No. 3222. Calculations based on new additions only.

TABLE 6—Continued. CROPS IN SERIES 44.

Lab. No.		Corn 1910.	Per cent. P_2O_5.	Gms. P_2O_5	Aver-age.	Gain over O.	Gain over E.	Per cent Recov-ered.
	Fifth crop, Series 44.							
956	1-O	12.0	.30	.0360	.0546			
	2-O	43.0	.17	.0731				
	3-AC	36.6	.24	.0878	.0887	.0341		22.3
	4-AC	40.7	.22	.0895				
	5-P*	20.4	.22	.0449	.0620	.0074		2.5
	6-P	31.6	.25	.0790				
	7-Ex	41.8	.21	.0878	.0879	.0333		29.6
	8-Ex	40.0	.22	.0880				
	9-AcEx	42.2	.32	.1350	.1314		.0435	29.0
	10-ACEx	42.6	.30	.1278				
	11-PEx	29.5	.29	.0855	.0841		0	0
	12-PEx	39.4	.21	.0827				

*If No. 5 excluded, availability of P—8.1.

Lab. No.		Sorghum 1910.	Per cent P_2O_5.	Gms. P_2O_5.	Aver-age.	Gain over O.	Gain over E.	Per cent recov-ered.
	Sixth crop, Series 44.							
1956	1-O	2.5	.46	.0115	.0170			
	2-O	7.0	.32	.0224				
	3-AC	4.4	.66	.0290	.0233	.0063		4.2
	4-AC	3.3	.53	.0175				
	5-P*	0.9	.62	.0056	.0180	.0010		0.3
	6-P	8.7	.35	.0304				
	7-Ex	15.4	.32	.0493	.0438	.0268		23.8
	8-Ex	16.6	.23	.0382				
	9-ACEx	10.2	.50	.0510	.0640		.0202	13.5
	10-ACEx	20.8	.37	.0769				
	11-PEx	16.3	.35	.0570	.0596		.0158	5.3
	12-PEx	21.4	.29	.0621				

*If No. 5 excluded, availability of rock—6.3.

Lab. No.		Corn 1910.	Per cent P_2O_5.	Gms. P_2O_5	Aver-age.	Gain over O.	Gain over E.	Per cent Recov-ered.
	Seventh crop, Series 44.							
1956	1-O	11.2	.19	.0213	.0267			
	3-O	18.9	.17	.0321				
	3-AC	15.4	.18	.0277	.0399	.0132		8.8
	4-AC	28.9	.18	.0520				
	5-P	10.3	.20	.0206	.0252			0
	6-P	16.5	.18	.0297				
	7-Ex	24.9	.18	.0488	.0376	.0109		9.7
	8-Ex	16.9	.18	.0304				
	9-ACEx	39.2	.21	.0823	.0865		.0489	32.6
	10-ACEx	41.2	.22	.0906				
	11-PEx	36.4	.20	.0728	.0551		.0175	5.8
	12-PEx	20.8	.18	.0374				

*If No. 12 excluded, availability of P (with Ex) is 11.4.

TABLE 6—Continued. CROPS IN SERIES 44.

Lab. No.		Mustard 1909.	Per cent P_2O_5	Gms. P_2O_5	Aver-age.	Gain over O.	Gain over E.	Per ce recov ered.
	First crop, Series 44.							
2377	1-O	0.9	.20	.0018	.0042			
	2-O	2.4	.27	.0065				
	3-AC	1.0	.39	.0039	.0053	.0011		0
	4-AC	2.0	.33	.0066				
	5-P	2.4	.25	.0067	.0068	.0026		0
	6-P	1.5	.46	.0069				
	7-Ex	2.0	.46	.0092	.0079	.0037		2
	8-Ex	1.2	.54	.0065				
	9-ACEx	1.2	.73	.0088	.0104		.0025	1
	10-ACEx	2.0	.60	.0120				
	11-PEx	1.4	.46	.0064	.0097		.0018	0
	12-PEx	3.0	.43	.0129				

Lab. No.		Corn 1910.	Per cent P_2O_5.	Gms. P_2O_5.	Aver-age.	Gain over O.	Gain over E.	Per cen Recov ered.
	Second crop, Series 44							
2377	1-O	43.5	.24	.1044	.1036			
	2-O	60.4	.17	.1027				
	3-AC	64.5	.22	.1419	.1347	.0311		20.
	4-AC	63.7	.19	.1274				
	5-P	48.4	.30	.0968	.1014			
	6-P	50.5	.21	.1060				
	7-Ex	47.1	.27	.1272	.1104	.0068		5.
	8-Ex	40.7	.23	.0936				
	9-ACEx	73.0	.18	.1387	.1508		.0404	26.
	10-ACEx	62.6	.30	.1628				
	11-PEx	53.0	.21	.1113	.1108		.0004	0.
	12-PEx	58.0	.19	.1102				

Lab. No.		Sorghum 1910.	Per cent P_2O_5.	Gms. P_2O_5.	Aver-age.	Gain over O.	Gain over E.	Per cen recov-ered.
	Third crop, Series 44.							
2377	1-O	11.4	.38	.0433	.0443			
	2-O	13.7	.33	.0452				
	3-AC	11.7	.46	.0538	.0594	.0151		10.1
	4-AC	13.8	.47	.0649				
	5-P	15.2	.32	.0486	.0450	.0007		0.2
	6-P	12.9	.32	.0413				
	7-Ex	17.2	.36	.0619	.0558	.0115		8.7
	8-Ex	14.2	.35	.0497				
	9-ACEx	12.6	.49	.0617	.0658		.0100	6.7
	10-ACEx	13.7	.51	.0699				
	11-PEx	13.2	.36	.0475	.0470			0
	12-PEx	14.1	.33	.0465				

Lab. No.		Mustard 1911.	Per cent P_2O_5	Gms. P_2O_5	Aver-age.	Gain over O.	Gain over E.	Per cent recov-ered.
	Fourth crop, Series 44							
2377	1-O	1.0	.50	.0050	.0080			
	2-O	2.2	.50	.0110				
	3-AC*	4.8	.50	.0240	.0205	.0125		8.3
	4-AC	3.4	.50	.0170				
	5-P	3.2	.50	.0160	.0098	.0018		0.6
	6-P	0.7	.50	.0035				
	7-Ex	2.3	.50	.0115	.0155	.0075		6.6
	8-Ex	3.9	.50	.0195				
	9-ACEx	5.9	.50	.0295	.0273		.0118	7.8
	10-ACEx	5.0	.50	.0250				
	11-PEx	3.3	.50	.0165	.0235		.0080	2.3
	12-PEx	6.1	.50	.0305				

*New additions of P, Ex and AC. Ex—1125 gms P_2O_5 No. 32222. Calculations based on new addition.

TABLE 6—Continued. CROPS IN SERIES 44.

Lab. No.		Corn 1911.	Per cent P_2O_5.	Gms. P_2O_5.	Aver-age.	Gain over O.	Gain over E.	Per cent Recov-ered.
	Fifth crop, Series 44.							
2377	1-O	15.3	.19	.0291	.0406			
	2-O	23.7	.22	.0521				
	3-AC	41.0	.19	.0779	.0729	.0323		21.5
	4-AC	29.5	.23	.0678				
	5-P	23.2	.21	.0487	.0368			0
	6-P	11.3	.22	.0249				
	7-Ex	44.8	.21	.0941	.0880	.0474		42.1
	8-Ex	29.2	.28	.0818				
	9-ACEx	43.5	.26	.1131	.1178		.0298	19.2
	10-ACEx	53.2	.23	.1224				
	11-PEx*	38.3	.23	.0881	.0728		0	0
	12-PEx	19.8	.29	.0574				

*If No. 11, PEx excluded, availability of rock is still zero.

Lab. No.		Sorghum 1911.	Per cent P_2O_5.	Gms. P_2O_5.	Aver-age.	Gain over O.	Gain over E.	Per cent recov-ered.
	Sixth crop, Series 44.							
2377	1-O	1.5	.35	.0053	.0158			
	2-O	11.4	.23	.0262				
	3-AC	28.5	.23	.0655	.0410	.0252		16.8
	4-AC	4.0	.41	.0164				
	5-P	4.8	.34	.0163	.0130			0
	6-P	3.7	.26	.0096				
	7-Ex	20.7	.21	.0435	.0464	.0306		27.2
	8-Ex	15.4	.32	.0493				
	9-ACEx*	1.6	.65	.0104	.0412		0	0
	10-ACEx	27.7	.26	.0720				
	11-PEx	17.4	.27	.0470	.0360			
	12-PEx*	5.2	.48	.0250			0	0

*If No. 9 excluded, availability of acid phosphate is 171 per cent.
*If No. 12 excluded, availability of rock phosphate is 0.2 per cent.

Lab. No.		Mustard 1910.	Per cent P_2O_5	Gms. P_2O_5	Aver-age.	Gain over O.	Gain over E.	Per cent recov-ered.
	First crop, Series 44.							
2378	1-O	1.0	.30	.0031	.0031			
	2-O	.7						
	3-AC	.5	.25	.0011	.0046	.0015		1.0
	4-AC	2.5	.32	.0080				
	5-P	1.0	.41	.0041	.0028	0		0
	6-P	.7	.20	.0014				
	7-Ex	1.0	.31	.0031	.0050	.0019		1.4
	8-Ex	2.0	.34	.0068				
	9-ACEx	3.2	.63	.0202	.0199		.0149	9.9
	10-ACEx	3.3	.59	.0195				
	11-PEx	1.2	.34	.0041	.0042		0	0
	12-PEx	1.2	.36	.0043				

TABLE 6—Continued. CROPS IN SERIES 44.

Lab. No.		Corn 1910.	Per cent P_2O_5.	Gms. P_2O_5.	Average.	Gain over O.	Gain over E.	Per cent Recovered.
	Second crop, Series 44							
2378	1-O	27.0	.21	.0567	.0569			
	2-O	27.2	.21	.0571				
	3-AC	51.1	.19	.1085	.1024	.0455		30.3
	4-AC	53.5	.18	.0963				
	5-P	19.5	.19	.0371	.0465	0		0
	6-P	24.3	.23	.0559				
	7-Ex	32.1	.22	.0706	.0737	.0168		12.7
	8-Ex	36.5	.21	.0767				
	9-ACEx	53.3	.18	.0959	.0936		.0199	13.2
	10-ACEx	53.7	.17	.0915				
	11-PEx	38.0	.20	.0760	.0712		0	0
	12-PEx	33.2	.20	.0664				

Lab. No.		Sorghum 1910.	Per cent P_2O_5.	Gms P_2O_5.	Average.	Gain over O.	Gain over E.	Per cent recovered.
	Third crop, Series 44.							
2378	1-O	18.7	.23	.0338	.0382			
	2-O	20.3	.21	.0426				
	3-AC	14.5	.34	.0493	.0478	.0096		6.4
	4-AC	12.5	.37	.0462				
	5-P	12.3	.25	.0307	.0368	0		0
	6-P	22.6	.19	.0429				
	7-Ex	23.2	.20	.0464	.0491	.0109		7.5
	8-Ex	23.5	.22	.0517				
	9-ACEx	15.2	.36	.0698	.0631		.0140	9.3
	10-ACEx	17.1	.33	.0564				
	11-PEx	18.3	.28	.0512	.0447		0	0
	12-PEx	14.1	.27	.0381				

Lab. No.		Mustard 1911.
	Fourth crop, Series 44.	
2378	1-O	1.8
	2-O	1.9
	3-AC*	2.4
	4-AC	2.5
	5-P	1.7
	6-P	1.8
	7-Ex	2.2
	8-Ex	2.0
	9-ACEx	2.0
	10-ACEx	2.7
	11-PEx	1.8
	12-PEx	1.9

*New additions of P, Ex, and AC, Ex—1125 gm. P_2O_5 No. 3222. Calculations based on new addition.

TABLE 6—Continued CROPS IN SERIES 44.

Lab No.		Corn 1911.	Per cent P_2O_5.	Gms. P_2O_5.	Average.	Gain over O.	Gain over E.	Per cent Recovered.
	Fifth crop, Series 44.							
2378	1-O	9.9	.20	.0198	.0302			
	2-O	23.9	.17	.0406				
	3-AC	48.0	.14	.0672	.0546	.0244		16.3
	4-AC	32.3	.13	.0420				
	5-P	26.4	.22	.0581	.0511	.0209		7.0
	6-P	21.0	.21	.0441				
	7-Ex	42.8	.17	.0728	.0658	.0356		31.6
	8-Ex	39.2	.15	.0588				
	9-ACEx	57.3	.17	.0974	.0925		.0267	17.1
	10-ACEx	48.6	.18	.0875				
	11-PEx	36.5	.22	.0803	.0717		.0059	1.9
	12-PEx	48.5	.13	.0631				

Lab. No.		Sorghum 1911.	Per cent P_2O_5.	Gms. P_2O_5.	Average.	Gain over O.	Gain over E.	Per cent recovered.
	Sixth crop, Series 44.							
2378	1-O	.7	.24	.0017	.0148			
	2-O	12.1	.23	.0278				
	3-AC	24.0	.21	.0504	.0382	.0234		15.6
	4-AC	8.1	.32	.0259				
	5-P	17.4	.26	.0452	.0370	.0222		7.4
	6-P	9.3	.31	.0288				
	7-Ex	16.1	.24	.0386	.0399	.0251		22.3
	8-Ex	19.6	.21	.0412				
	9-ACEx	32.1	.20	.0642	.0574		.0175	11.7
	10-ACEx	18.7	.27	.0505				
	11-PEx	22.3	.25	.0558	.0536		.0137	4.6
	12-PEx	25.7	.20	.0514				

TABLE 7. CROPS IN SERIES 45.

Lab. No.		Sorghum 1910.	Per cent P_2O_5.	Gms. P_2O_5.	Average.	Gain over O.	Gain over E.	Per cent recovered.
	First crop, Series 45.							
3333	1-O	41.5	.18	.0747	.0833			
	2-O	51.0	.18	.0918				
	3-AC	47.9	.20	.0958	.0998	.0165		16.5
	4-AC	45.1	.23	.1037				
	5-R	42.7	.21	.0897	.0810	0		0
	6-R	42.5	.17	.0722				
	7-Ex	45.4	.19	.0862	.0770	0		0
	8-Ex	45.2	.15	.0678				
	9-ACEx	6.4	.16	.1024	.0984		.0214	21.4
	10-ACEx	49.1	.19	.0944				
	11-REx	48.2	.17	.0819	.0856		.0086	5.7
	12-REx	52.5	.17	.0892				

Lab. No.		Mustard 1911.
	Second crop, Series 45.	
3333	1-O	4.3
	2-O	2.5
	3-AC	4.5
	4-AC	7.1
	5-R	6.5
	6-R	8.6
	7-Ex	4.5
	8-Ex	7.7
	9-ACEx	8.4
	10-ACEx	8.8
	11REx	10.6
	12REx	7.2

TABLE 7—Continued. CROPS IN SERIES 45.

Lab. No.		Corn 1911.	Per cent P_2O_5.	Gms. P_2O_5.	Average.	Gain over O.	Gain over E.	Per cent Recovered.
	Third crop, Series 45.							
3333	1-O	28.3	.15	.0424	.0433			
	2-O	29.4	.15	.0441				
	3-AC	35.4	.14	.0496	.0493	.0060		6.0
	4-AC	32.7	.15	.0490				
	5-R	33.4	.14	.0468	.0455	.0022		1.7
	6-R	34.0	.13	.0442				
	7-Ex	29.8	.16	.0477	.0458	.0025		6.0
	8-Ex	29.2	.15	.0438				
	9-ACEx	34.5	.15	.0517	.0489		.0031	3.1
	10-ACEx	30.7	.15	.0460				
	11-REx	37.1	.15	.0556	.0535		.0077	5.1
	12-REx	34.3	.15	.0514				

Lab. No.		Sorghum 1910.	Per cent P_2O_5.	Gms. P_2O_5.	Average.	Gain over O.	Gain over E.	Per cent recovered.
	First crop, Series 45.							
3653	1-KN	7.0	.14	.0098	.0090			
	2-KN	6.4	.13	.0083				
	3-ACKN	42.0	.12	.0504	.0534	.0444		44.4
	4-ACKN	43.3	.13	.0563				
	5-KNR	22.0	.13	.0286	.0260	.0170		11.3
	6-KNR	19.5	.12	.0234				
	7-KNEx	10.0	.14	.0140	.0148	.0058		13.8
	8-KNEx	12.0	.13	.0156				
	9-KNACEx	40.2	.12	.0482	.0421		0.273	27.3
	10-KNACEx	37.7	.13	.0390				
	11-KNREx	25.2	.13	.0328	.0315		0.167	11.1
	12-KNREx	25.2	.12	.0302				

Lab. No.		Mustard 1911.
	Second crop, Series 45.	
3653½	1-O	
	2-O	2.7
	3-AC	3.5
	4-AC	3.5
	5-R	1.3
	6-R	2.9
	7-Ex	3.0
	8-Ex	2.8
	9-ACEx	5.8
	10-ACEx	2.3
	11-REx	3.6
	12-REx	4.3

Lab. No.		Corn 1911.	Per cent P_2O_5	Gms. P_2O_5	Average.	Gain over O.	Gain over E.	Per cent recovered.
	Third crop, Series 45.							
3653	1-O	8.7	.18	.0157	.0153			
	2-O	8.7	.17	.0148				
	3-AC	16.4	.16	.0262	.0262	.0109		10.9
	4-AC	17.4	.15	.0261				
	5-R	9.6	.17	.0163	.0200	.0047		3.1
	6-R	15.7	.15	.0236				
	7-Ex	11.6	.17	.0197	.0152			36.7
	8-Ex	6.6	.16	.0106				
	9-ACEx	19.6	.12	.0235	.0239		.0087	8.7
	10-ACEx	18.6	.13	.0242				
	11-REx	17.2	.17	.0292	.0262		.0110	7.3
	12-REx	14.5	.16	.0232				

TABLE 7—Continued. CROPS IN SERIES 45.

Lab. No.		Sorghum 1910.	Per cent P_2O_2	Gm. P_2O_5	Average Gms.	Increase P_2O_5 over O Gm.	Increase E Gm.	Per cent recovered.
	Series 45. First crop.							
3652	1-O	18.6	.13	.0242	.0276	.....	.....	.....
	2-O	22.1	.14	.0309	.....	.....	.....	.....
	3-AC	57.2	.14	.0801	.0774	.0498	.....	49.8
	4-AC	46.7	.16	.0747	.....	.....	.....	.....
	5-R	28.2	.14	.0395	.0363	.0087	.....	5.8
	6-R	27.5	.12	.0330	.....	.....	.....	.....
	7-Ex	23.4	.13	.0304	.0281	.0005	.....	1.0
	8-Ex	23.5	.11	.0258	.....	.....	.....	.....
	9-ACEx	46.7	.15	.0700	.0709	.....	.0428	42.8
	10-ACEx	44.9	.16	.0718	.....	.....	.....	.....
	11-REx	33.5	.11	.0368	.0388	.....	.0107	7.1
	12-REx	21.3	.13	.0407	.....	.....	.....	.....

Lab. No.		Mustard 1911.
	Second crop, Series 45.	
3652	1-O	2.6
	2-O	5.7
	3-AC	3.8
	4-AC	5.0
	5-R	5.6
	6-R	4.2
	7-Ex	3.2
	8-Ex	3.2
	9-ACEx	4.8
	10-ACEx	4.7
	11-REx	7.1
	12-REx	7.6

Lab. No.		Corn 1911	Per cent P_2O_5	Gms. P_2O_5	Aver-age.	Gain over O	Gain over Ex	Per cent recov-ered.
	Series 45, Third crop.							
3652	1-O	13.5	.15	.0202	.0210	.....	.....	.....
	2-O	16.7	.13	.0217	.....	.....	.....	.....
	3-AC	16.2	.15	.0243	.0259	.0049	.....	4.9
	4-AC	17.1	.16	.0274	.....	.....	.....	.....
	5-R	19.7	.13	.0256	.0187	0	.....	0
	6-R	7.4	.16	.0118	.....	.....	.....	.....
	7-Ex	11.8	.16	.0189	.0200	.....	.....	48.2
	8-Ex	14.0	.15	.0210	.....	.....	.....	.....
	9-ACEx	16.7	.15	.0250	.0272	.....	.0072	7.2
	10-ACEx	21.0	.14	.0294	.....	.....	.....	.....
	11-REx	23.3	.14	.0326	.0291	.....	.0091	6.1
	12-REx	18.3	.14	.0256	.....	.....	.....	.....

Lab. No.		Corn 1912	Per cent P_2O_5	Gms. P_2O_5	Aver-age.	Gain over O	Gain over Ex	Per cent recov-ered.
	Series 45, Fourth crop.							
3652	1-O	11.3	.14	.0158	.0212	.....	.....	.....
	2-O	15.6	.17	.0265	.....	.....	.....	.....
	3-AC*	25.3	.14	.0354	.0403	.0191	.....	21.1
	4-AC	32.3	.14	.0452	.....	.....	.....	.....
	5-R	18.6	.14	.0260	.0164	0	.....	0
	6-R	3.6	.19	.0068	.....	.....	.....	.....
	7-Ex	9.1	.17	.0155	.0174	.....	.....	41.9
	8-Ex	9.6	.20	.0192	.....	.....	.....	.....
	9-ACEx	26.4	.13	.0343	.0435	.....	.0261	28.9
	10-ACEx	37.6	.14	.0526	.....	.....	.....	.....
	11-REx	16.8	.15	.0252	.0340	.....	.0166	9.1
	12-Rex	23.8	.18	.0428	.....	.....	.....	.....

*New additions of AC and R. Previous additions disregarded.

TABLE 8. CROPS IN SERIES 46.

Lab. No.		Corn 1911	Per cent P_2O_5	Gms. P_2O_5	Gain over O	Gain over Ex	Per cent recovered.
	Series 46, First crop.						
3654	1-O	13.4	.21	.0281			
	2-AC	55.1	.14	.0771	.0490		31.4
	3-R	15.6	.16	.0250	0		0
	4-E	15.9	.16	.0254	0		0
	5-ACE	42.2	.14	.0591		.0337	21.6
	6-RE	21.7	.14	.0304		.0050	1.5

Lab. No.		Sorghum 1911	Per cent P_2O_5	Gms. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 46, Second crop.						
3654	1-O	11.5	.11	.0127			
	2-AC	26.6	.12	.0319	.0192		12.3
	3-R	22.9	.13	.0298	.0171		5.3
	4-E	12.9	.12	.0155	.0028		6.6
	5-ACE	25.4	.10	.0254		.0099	6.6
	6-RE	26.7	.13	.0347		.0192	6.0

Lab. No.		Corn 1911	Per cent P_2O_5	Gms. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 46, Second crop.						
3656	1-O	27.0	.15	.0405			
	2-AC	56.6	.13	.0736	.0331		21.2
	2-R	39.4	.15	.0591	.0186		5.8
	4-E	28.0	.15	.0420	.0015		3.6
	5-ACE	58.5	.17	.0995		.0575	36.9
	6-ER	37.5	.17	.0638		.0218	6.8

Lab. No.		Sorghum 1911	Per cent P_2O_5	Gms. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 46, Second crop.						
3656	1-O	9.0	.17	.0153			
	2-AC	16.7	.16	.0267	.0114		7.3
	3-R	23.1	.16	.0370	.0217		6.7
	4-E	12.7	.15	.0190	.0037		8.8
	5-ACE	17.3	.18	.0311		.0121	7.7
	6-ER	28.0	.14	.0392		.0202	6.2

Lab. No.		Corn 1911	Per cent P_2O_5	Gms. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 46, First crop.						
3975	1-O	14.9	.17	.0253			
	2-A. 13571=.156	54.8	.14	.0767	.0514		32.9
	3-R. 4570=.323	36.7	.16	.0687	.0434		13.4
	4-E. 4559=.042	14.6	.16	.0234	0		0
	5-EA	48.6	.12	.0583		.0349	22.3
	6-ER	27.2	.15	.0408		.0074	2.3

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TABLE 8—C... CROPS IN SERIES 46.

Lab. No.		Sorghum 1911	Per cent P_2O_5	Gms. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 46, Second crop.						
3975	1-O	9.4	.12	.0113			
	2-A	32.6	.13	.0424	.0311		20.0
	3-R	34.7	.12	.0416	.0303		9.4
	4-E	12.7	.13	.0165	.0052		12.4
	5-EA	29.0	.16	.0464		.0299	19.2
	6-ER	23.8	.12	.0286		.0121	3.8

Lab. No.		Corn 1911	Per cent P_2O_5	Gms. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 46, First crop.						
2409	1-O	61.3	.20	.1226			
	2-AC	66.0	.21	.1386	.0160		10.2
	3-R	58.8	.25	.1470	.0244		7.1
	4-Ex	57.5	.20	.1150			0
	5-ACEx	69.7	.20	.1394		.0244	15.4
	6-REx	62.0	.23	.1426		.0276	8.5

Lab. No.		Sorghum 1911	Per cent P_2O_5	Gms. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 46, Second crop.						
2409	1-O	18.6	.19	.0353			
	2-AC	23.0	.22	.0506	.0153		9.8
	3-R	26.7	.21	.0561	.0208		6.4
	4-Ex	23.9	.20	.0478	.0125		30.0
	5-ACEx	24.6	.28	.0689		.0221	14.2
	6-REx	26.7	.20	.0534		.0056	1.8

Lab. No.		Corn 1911	Per cent P_4O_5	Gms. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 46, First crop.						
2829	1-O	38.8	.34	.1319			
	2-E	37.5	.36	.1350	.0031		7.4
	3-EA	41.7	.28	.1168			0
	4-ER	39.7	.36	.1429		.0079	2.4

Lab. No.		Sorghum 1911	Per cent P_2O_5	Gms. P_2O_3	Gain over O	Gain over E	Per cent recovered.
	Series 46, Second crop.						
2829	1-O	26.5	.29	.0768			
	2-E	18.7	.37	.0692			0
	3-EA	24.6	.34	.0836		.0144	9.2
	4-ER	28.0	.33	.0924		.0232	7.1

TABLE 8—Continued. CROPS IN SERIES 46.

Lab. No.		Corn 1911	Per cent P_2O_5	Gms. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 46, First crop.						
2831	1-O	55.0	.16	.0880			
	2-A	46.3	.24	.1111	.0231		14
	3-R	43.9	.19	.0834	0	0	
	4-E	47.0	.18	.0846	0		
	5-EA	54.6	.24	.1310		.0464	29
	6-ER	48.4	.22	.1065		.0219	6

Lab. No.		Sorghum 1911	Per cent P_2O_5	Gms. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 46, Second crop.						
2831	1-O	39.0	.18	.0702			
	2-A	45.4	.20	.0908	.0206		13.
	3-R	43.0	.19	.0817	.0115		3.
	4-E	44.9	.17	.0763	.0061		14.
	5-EA	44.5	.23	.1023		.0260	16.
	6-ER	44.2	.20	.0824		.0061	1.

TABLE 9. CROPS IN SERIES 47.

Lab. No.		Corn 1911	Per cent P_2O_5	Gms. P_2O_5	Gain over O	Gain over E	Per cent addition recovered.
	Series 47, First crop.						
3634	1-O	6.7	.16	.0107			
	2-E	7.5	.15	.0112	.0005		1.
	3-EA	29.7	.12	.0356		.0244	15.
	4-ER	6.7	.16	.0107		.0000	
	5-ER$_2$	6.2	.15	.0093		.0000	

Lab. No.		Sorghum 1911	Per cent P_2O_5	Gms. P_2O_5	Gain over O	Gain over Ex	Per cent recovered.
	Series 47, Second crop.						
3634	1-O	3.9	.19	.0074			
	2-E	6.2	.17	.0105	.0031		7.7
	3-EA	21.7	.21	.0456		.0351	22.5
	4-ER	6.6	.15	.0099		0	0
	5-ER$_2$	6.1	.15	.0091		0	0

Lab. No.		Corn 1911	Per cent P_2O_5	Gms. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 47, First crop.						
4582	1-O	50.1	.20	.1002			
	2-E	48.3	.24	.1159	.0157		13.1
	3-EA	54.0	.28	.1512		.0353	22.6
	4-ER$_1$	53.2	.24	.1277		.0118	3.6
	5-ER$_2$	47.7	.24	.1145			0
	6-ER$_3$	53.6	.24	.1296		.0137	4.5

TABLE 9—Continued. CROPS IN SERIES 47.

Lab. No.		Sorghum 1911	Per cent P_2O_2	Gms. P_2O_5	Gain over O	Gain over Ex	Per cent recovered.
	Series 47, First crop.						
4582	1-O	3.9	.49	.0191			
	2-E	8.2	.45	.0369	.0178		14.8
	3-EA	7.4	.49	.0363			0
	4-ER_1	12.1	.35	.0424		.0055	1.8
	5-ER_2	12.1	.38	.0460		.0091	2.8
	6-ER_3	12.4	.38	.0471		.0102	0.3

Lab. No.		Corn 1911	Per cent P_2O_5	Gms. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 47, First crop.						
4586	1-O	7.5	.16	.0120			
	2-E	31.5	.13	.0409	.0289		24.1
	3-EA	47.3	.13	.0615		.0206	13.2
	4-ER_1	33.7	.14	.0472		.0063	2.0
	5-ER_2	46.5	.13	.0604		.0195	6.4
	6-ER_3	46.6	.13	.0606		.0197	6.4

Lab. No.		Sorghum 1911	Per cent P_2O_5	Gms. P_2O_5	Gain over O	Gain over Ex	Per cent recovered.
	Series 47, First crop.						
4586	1-O	2.7	.21	.0057			
	2-E	8.3	.16	.0133	.0076		6.3
	3-EA	15.6	.25	.0390		.0257	16.5
	4-ER_1	23.4	.22	.0515		.0382	11.7
	5-ER_2	22.3	.23	.0513		.0380	11.8
	6-ER_3	23.6	.22	.0519		.0386	12.2

Lab. No.		Corn 1911	Per cent P_2O_5	Gms. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 47, First crop.						
4587	1-O	31.4	.17	.0534			
	2-E	47.6	.17	.0809	.0285		23.7
	3-EA	59.0	.18	.1062		.0243	15.6
	4-ER_1	45.9	.19	.0872		.0053	1.7
	5-ER_2	45.1	.17	.0767			0
	6-ER_3	47.4	.19	.0901		.0082	2.6
	7-E	43.6	.19	.0828			

Lab. No.		Sorghum 1911	Per cent P_2O_5	Gms. P_2O_5	Gain over O	Gain over Ex	Per cent recovered.
	Series 47, Second crop.						
4587	1-O	17.4	.18	.0313			
	2-E	28.8	.18	.0518	.0205		17.1
	3-EA	27.4	.22	.0603		.0071	4.6
	4-ER_1	22.3	.23	.0513		0	0
	5-ER_2	29.8	.19	.0566		.0034	1.0
	6-ER_3	27.8	.21	.0584		.0052	1.6
	7-E	24.9	.22	.0547			

TABLE 10. CROPS IN SERIES 48.

Lab. No.		1913 weight corn	Analysis per cent	Gm. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 48, First crop.						
2342	1-O	17.5	.18	.0315	.....	.....	.....
	2-E	26.5	.16	.0424	.0109	.....	12.6
	3-EA	43.2	.15	.0644	.....	.0224	29.0
	4-ER	28.5	.18	.0513	.....	.0089	5.8
	5-A	27.0	.16	.0432	.0117	.....	15.2
		Sorghum 1913					
	Second crop—Sorghum.						
	1-O	14.1	.13	.0188	.....	.....	.....
	2-E	26.3	.14	.0368	.0180	.....	20.8
	3-EA	29.0	.15	.0435	.....	.0067	8.6
	4-ER	28.4	.15	.0426	.....	.0058	3.8
	5-A	22.5	.15	.0338	.0150	.....	19.5

Lab. No.		Corn 1914	Per cent P_2O_5	Gm. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Sereis 48, Third crop.						
2342	1-O	8.7	.17	.0148	.....	.....	.....
	2-E	10.4	.18	.0187	.0039	.....	4.5
	3-EA	14.4	.19	.0274	.....	.0087	11.3
	4-ER	20.5	.15	.0308	.....	.0121	7.9
	5-A	10.1	.15	.0152	.0004	.....	0.5
		Sorghum 1914					
	Fourth crop.						
	1-O	14.0	.16	.0224	.....	.....	.....
	2-E	15.8	.14	.0221	0	.....	0
	3-EA	15.7	.13	.0204	.....	0	0
	4-ER	19.0	.14	.0266	.....	.0045	2.9
	5-A	13.5	.19	.0257	.0033	.....	4.3

Lab. No.		1913 weight corn	Analysis per cent	Gm. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 48, First crop.						
2348	1-O	6.5	.26	.0169	.....	.....	.....
	2-E	18.1	.18	.0326	.0157	.....	18.2
	3-EA	30.3	.20	.0606	.....	.0280	36.3
	4-ER	18.0	.20	.0360	.....	.0191	12.4
	5-A	20.5	.21	.0431	.0262	.....	33.7
		Sorghum 1913					
	Second crop.						
	1-O	11.9	.17	.0202	.....	.....	.....
	2-E	18.6	.16	.0298	.0096	.....	11.1
	3-EA	22.6	.17	.0384	.....	.0086	11.1
	4-ER	19.3	.23	.0444	.....	.0146	9.5
	5-A*	14.1	.21	.0296	.0094	.....	12.0

*Four plants only.

TABLE 10—Continued. CROPS IN SERIES 48.

Lab. No.		Corn 1914	Per cent P_2O_5	Gm. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 48, Third crop.						
2348	1-O	4.7	.22	.0103	.....	.....	.....
	2-E	7.3	.18	.0131	.0028	.....	3.2
	3-EA	11.3	.14	.0158	.....	.0055	7.1
	4-ER	9.2	.18	.0166	.....	.0063	4.1
	5-A	9.0	.18	.0172	.0069	.....	8.9
		Sorghum 1914					
	Fourth crop.						
	1-O	2.2	.17	.0037	.....	.....	.....
	2-E	3.9	.32	.0125	.0088	.....	10.2
	3-EA	3.3	.24	.0079	.....	0	0
	4-ER	3.5	.22	.0077	.....	0	0
	5-A	3.5	.33	.0116	.0079	.....	10.3

Lab. No.		1913 weight corn	Analysis per cent	Gm. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 48, First crop.						
5095	1-O	21.0	.15	.0321	.....	.....	.....
	2-E	44.0	.15	.0660	.0339	.....	39.2
	3-EA	47.5	.16	.0760	.....	.0439	56.8
	4-ER	48.5	.16	.0776	.....	.0455	29.7
	5-A	40.0	.15	.0600	.0279	.....	36.1
		Sorghum 1913					
	1-O	6.3	.14	.0088	.....	.....	.....
	2-E	14.9	.17	.0253	.0165	.....	19.1
	3-EA	13.6	.15	.0204	.....	0.0000	0
	4-ER	15.1	.17	.0257	.....	.0003	1.9
	5-A	8.6	.22	.0189	.0101	.....	13.0

Lab. No.		Corn 1914	Per cent P_2O_5	Gm. P_2O_5	Gain over O	Gain over E	Per cen recov-ered.
	Series 48, Third crop.						
5095	1-O	6.2	.15	.0093	.....	.....	.....
	2-E	9.5	.14	.0133	.0040	.....	4.6
	3-EA	13.7	.15	.0206	.....	.0073	9.4
	4-ER	13.2	.21	.0277	.....	.0134	8.7
	5-A	11.4	.15	.0171	.0078	.....	10.1
		Sorghum 1914					
	Fourth crop.						
	1-O	0.1	.47	.0005	.....	.....	.....
	2-E	3.5	.20	.0070	.0065	.....	7.5
	3-EA	1.7	.29	.0049	.....	0	0
	4-ER	0.1	.52	.0005	.....	0	0
	5-A	3.7	.24	.0089	.0084	.....	10.9

TABLE 10—Continued. CROPS IN SERIES 48.

Lab. No		1913 weight corn	Analysis per cent	Gm. P_2O_5	Gain over O	Gain over E	Per cent recovered.
5701	Series 48, First crop						
	1-O	10.9	.21	.0229			
	2-E	22.7	.16	.0363	.0142		16.4
	3-EA	42.5	.16	.0680		.0317	41.0
	4-ER	27.2	.18	.0490		.0127	8.3
	5-A	29.4	.15	.0441	.0320		41.4
	6-R	15.8	.17	.0269	.0048		3.1
	7-O	11.2	.19	.0213			
		Sorghum 1913					
	Second crop.						
	1-O	11.2	.18	.0202			
	2-E	20.0	.15	.0300	.0132		15.3
	3-EA	17.6	.24	.0420		.0120	15.5
	4-ER	20.8	.16	.0333		.0033	2.2
	5-A	16.0	.14	.0224	.0056		7.2
	6-R	15.1	.14	.0211	.0043		2.8
	7-O	9.5	.14	.0133			

Lab. No.		Corn 1914	Per cent P_2O_5	Gm. P_2O_5	Gain over O	Gain over E	Per cent recovered.
5701	Third crop.						
	1-O	3.2	.25	.0080			
	2-E	4.5	.19	.0086	.0012		1.4
	3-EA	3.5	.20	.0070		0	0
	4-ER	7.0	.17	.0119		.0039	2.5
	5-A	5.2	.17	.0088	.0014		1.8
	6-R	7.0	.17	.0119	.0045		2.9
	7-O	3.2	.21	.0067			
		Sorghum 1914					
	Fourth crop.						
	1-O	5.5	.20	.0110			
	2-E	9.5	.19	.0181	.0071		8.2
	3-EA	6.5	.20	.0130		0	0
	4-ER	8.8	.20	.0176		0	0
	5-A	5.0	.33	.0165	.0055		7.1
	6-R	10.8	.20	.0216	.0106		6.9
	7-O	3.4	.32	.0109			

Lab. No.		1913 weight corn	Analysis per cent	Gm. P_2O_5	Gain over O	Gain over E	Per cent recovered.
6885	Series 48, First crop.						
	1-O	13.5	.16	.0216			
	2-E	39.2	.14	.0549	.0333		38.5
	3-EA	54.0	.14	.0756		.0206	26.7
	4-ER	44.7	.11	.0492		.0000	0
	5-A	49.2	.12	.0590	.0374		48.4
	6-R	35.2	.11	.0387	.0171		11.2
		Sorghum 1913					
	Second crop.						
	1-O	7.4	.13	.0096			
	2-E	11.7	.13	.0152	.0056		6.5
	3-EA	19.7	.16	.0315		.0163	21.1
	4-ER	29.3	.14	.0410		.0258	16.2
	5-A	14.1	.15	.0212	.0116		15.0
	6-R	15.	.12	.0180	.0084		5.5

TABLE 10—Continued. CROPS IN SERIES 48.

Lab. No.		Corn 1914	Per cent P_2O_5	Gm. P_2O_5	Gain over O	Gain over E	Per cent recovered.
	Series 48, Third crop.						
6885	1-O	3.4	.18	.0061			
	2-E	5.6	.19	.0106	.0045		5.2
	3-EA	10.1	.14	.0142		.0036	4.7
	4-ER	17.9	.14	.0251		.0190	12.4
	5-EA	7.5	.15	.0113	.0052		6.7
	6-ER	9.0	.18	.0162	.0101		6.6
		Sorghum 1914					
	Fourth crop.						
	1-O	4.0	.25	.0100			
	2-E	4.5	.31	.0140	.0040		4.6
	3-EA	6.5	.21	.0137			
	4-ER	10.7	.22	.0235		.0095	6.2
	5-A	5.0	.25	.0125	.0025		3.2
	6-R	9.7	.20	.0194	.0094		6.2

Series 45. Soils 3333, 3653, 3652. Weight 5 kg. Additions 1 gm. each potassium chloride and ammonium nitrate; 0.1 gm. available phosphoric acid in acid phosphate No. 3194; 0.15 gm. total phosphoric acid in phosphate rock No. 729; 5 gms. excrement No. 917, containing .0415 gm. phosphoric acid. Planted 1 gm. sorghum July 9, harvested September 3, 1910.

Second crop, mustard: added 1 gm. each ammonium nitrate and potassium sulphate; planted 1 gm. mustard October 13, 1910; killed by freeze and harvested January 3, 1911.

Third crop; corn: added 1 gm. each ammonium nitrate and potassium sulphate. Planted 1.8-1.9 gm. corn; 5 grains on March 24, 1911; thinned to 4 stalks on April 10, harvested June 22, 1911.

Fourth crop (3652 only); corn: added 1 gm. each ammonium nitrate and potassium sulphate; .09 gm. available phosphoric acid in acid phosphate 14068; 0.183 gm. total phosphoric acid in acid phosphate 4563. Planted corn April 10, 1912, harvested June 25, 1912.

Series 46. Soils 3654, 3656, 3975, 2409, 2829, 2831. Added 1 gm. each ammonium nitrate and sulphate of potash; 10 gms. excrement (E) No. 4559, containing .042 gm. phosphoric acid, 1 gm. acid phosphate No. 13571 equals .156 gm. available phosphoric acid; 1 gm. phosphate rock No. 4569 equals .322 gm. total phosphoric acid. Weights of pots: No. 2831, 8600 gms. soil; 3654, 8200 gms.; 3656, 8100 gms.; 3975, 7600 gms.; 2409, 6800 gms.; 2829, 6700 gms. planted 5 grains corn, 1.8-1.9 gms. on April 1, harvested June 14 to June 22, 1911.

Second crop; sorghum: Added 1 gm. ammonium nitrate. Planted sorghum June 23, 1911, harvested August 23 to September 9, 1911.

Series 47. Soils 4582, 4587, 4586. Weights: 6500 gms. of No. 4582; 7600 gms. of No. 4587; 7200 gms. of No. 4586. Additions: 1 gm. each ammonium nitrate and sulphate of potash; 10 gms. excrement No. 4561, carrying .120 gm. phosphoric acid; 1 gm. acid phosphate 13571, containing .156 gms. available phosphoric acid; 1 gm. rock phosphate No. 4569 R 1 with .326 gm. total phosphoric acid;

1 gm. rock phosphate R 2 No. 4570 with .323 gm. total phosphoric acid; 1 gm. rock phosphate R 3, No. 4479 with .306 gm. total phosphoric acid. Planted corn April 10, harvested June 16, 1911.

Second crop; sorghum: added 1 gm. ammonium nitrate. Planted 1 gm. sorghum 4582 June 26, harvested August 30, 1911; 4586 planted July 25, harvested October 17; 4587 planted July 25, harvested September 30.

Series 48. Soils 2342, 2348, 5095, 5701, 6885. Weight 5 kg. per pot. Additions: 1 gm. each ammonium nitrate and potassium sulphate; 8 gms. excrement No. 3258 containing .0864 gm. phosphoric acid; 0.5 gm. acid phosphate 24828, containing .0772 gm. available phosphoric acid; 0.5 gm. phosphate rock (R), containing .153 gm total phosphoric acid.

First crop; corn, 1913. Planted 5 grains corn 2.0-2.2 gms. on soil 2342, 2348, and 5095 on April 24; 5701 and 6885 on June 18, harvested on June 26, 1913.

Second crop; sorghum. Added 1 gm. each ammonium nitrate and potassium sulphate. Planted 2342, 5701 July 8, harvested September 13, 1913; planted 2348 July 8, harvested September 5; planted 5095 July 10, harvested September 4, 1913; planted 6885 on July 8, harvested September 5, 1913.

Third crop; corn: Added 1 gm. each potassium sulphate and ammonium nitrate. Planted April 16, harvested June 18, 1914.

Fourth crop; sorghum: Added 1 gm. each potassium sulphate and ammonium nitrate. Planted July 8, harvested September 5, 1914, except No. 2342, which was harvested September 21, 1914.

DESCRIPTION OF SOILS.

The analyses of the soils are given in Table 11.

844. Raywood, Liberty County; E. C. Carlyle, collector; rice soil

852. Orange, Orange County; black, heavy soil; rice soil.

1956. Between College and Bryan, Brazos County; Kyle's farm sand.

TABLE 11. COMPOSITION OF SOILS.

Lab. No.		Total phosphoric acid.	Nitrogen.	Potash acid soluble.	Lime.	Magnesia.	Active phosphoric acid.	Active potash.	Acid consumed.	Phosphoric acid absorbed	Acidity.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per million.	Per million.	Per cent.	Per cent.	Per million.
844	Raywood, Liberty county	.02	.09	.13	.65	.31	8.8	40	.....	76.9	0
852	Orange, Orange county	.02	.10	.14	.32	.26	17.9	.....	10.00	59.6	500
1956	Between College and Bryan, Brazos county	.037	.033	.07	.33	.06	75.3	105.8	1.48	3.3	.....
2342	Winsfield, Titus county	.038	.081	.20	.16	.20	7.2	131.6	3.03	64.9	0
2348	Mt. Pleasant, Titus county	.016	.027	.10	.14	.13	6.5	90.6	3.78	27.4	0
2377	Jacksonville, Cherokee county	.....	.030	.11	.09	.09	33.5	68.8	1.00	44.3	.....
2378	Dialville, Cherokee county	.020	.043	.09	.18	.12	8.7	153.0	2.4	59.0	0
2409	Nederland, Jefferson county	.037	.154	.37	.46	.43	131.9	147.5	10.9	75.3	0
2829	Pittsburg, Grayson county	.094	.071	.44	4.43	1.27	154.4	232.7	63.7	94.5	0
2831	Pittsburg, Grayson county	.035	.128	.29	.54	.31	13.1	169.4	14.1	74.5	0
3333	Waco, McLellan county	.020	.034	.21	.17	.17	21.1	155.3	3.4	12.4	0
3652	Lexington, Lee county	.014	.023	.05	.15	.11	5.0	73.7	1.0	9.7	200
3653	Lexington, Lee county	.030	.038	.....	.....	.....	11.0	52.5	1.5	8.2	.....
3654	Lexington, Lee county	.017	.018	.03	.20	.17	5.9	98.0	1.8	8.2	0
3656	Lexington, Lee county	.020	.021	.02	.07	.15	13.8	66.5	39.8	8.7	0
3975		.020	.040	.13	.14	.14	5.6	81.2	4.1	32.8	0
4582	Chandler, Henderson county	.020	.026	.06	.12	.05	31.5	99.9	2.0	.....	0
4586	Marquez	.025	.044	.29	.07	.10	2.5	102.5	2.0	84.0	600
4587	Argyle, Denton county	.025	.026	.09	.12	.06	12.1	130.6	1.3	38.7	0
5095		.015	.014	.05	.09	.11	14.4	63.7	1.0	.....	.....
5701	Katy, Fort Bend county	.....	.027	.06	.16	.05	5.0	40.0	0.50	30.3	.....
6885	San Antonio, Duval county	.....	.031	.18	.18	.10	6.2	185.0	1.5	21.0	0

2342. Lufkin fine sandy loam; Titus County; 0″-8″; Winsfield Route 2; collector, T. D. Rice; 16 miles west of town, south of creek north of road in field near fence, east and west lane leading to Daphn north of White Oak Creek; fairly productive, but uncultivated; level poor drainage; light brown color; hard to cultivate in wet years, an soil bakes in dry years; produces one-third to one-half bales cotton, o 15 to 20 bushels of corn.

2348. Norfolk fine sandy loam; 0″-10″; Titus County; 5 mile southeast of Mt. Pleasant, one-half mile from south Daingerfield road W. T. Edwards' farm; land only fair; has run down due to constan cropping of cotton; rolling, good drainage; light brown color; easil handled in wet and dry seasons; produces one-fourth to one-third bal cotton, or 15 to 20 bushels corn; sample taken on slope which is some what eroded and soil is poor from careless farming.

2377. Cherokee County, Jacksonville; J. B. McKnight, Route 1 gray sandy soil; in cultivation 15 years.

2378. Orangeburg fine sandy loam (probably); Cherokee County C. D. Jarret's farm near Dialville; red color, sandy; cultivated sinc 1885; box sample while in room No. 8 completely saturated with sul phur water from leak in drain trough.

2409. 0″-4″; Jefferson County; Koelemoy Bros., Nederland; sur face soil; upland; perfect drainage; soil holds moisture well; produce 2800 pounds rice, 800 corn.

2829. Wilson clay; 5″-36″; Grayson County; J. T. Bryant's place one-half mile southwest Pittsburg; no rocks in small sample.

2831. Wilson clay loam; 10″-36″; Grayson County; J. T. Bryant's place, one-half mile southeast Pittsburg; 4 per cent. gravel.

3333. Houston loam; 0″-10″; McLennan County; J. N. Worthy's place, four and one-half miles from Waco; good soil, upland, rolling prairie; light brown color; sandy; suffers from drouth; cultivated since 1882; small area on farm; no green crop, no manure; occurs in small patches through the Susquehanna fine sandy loam; cotton and corn chiefly grown; produces 25 to 30 bushels of corn, or one-half to three-fourths bales of cotton.

3652. Norfolk fine sand; 0″-12″; Lee County; Louis Gest's place, two miles west of Lexington; corner of roads; not in cultivation; packs; does not wash.

3653. Norfolk fine sand; 12″-24″; subsoil to 3652.

3654. Orangeburg fine sand; 0″-12″; Lee County; Louis Gest's place, two miles west of Lexington; 25 years in cultivation; does not pack; good; nitrogenous rolling soil; holds moisture; produces 20 bushels of corn, one-half bale of cotton, or 100 bushels of potatoes.

3656. Orangeburg fine sandy loam; 0″-12″; Lee County, Louis Gest's place, two miles east of Lexington; holds moisture well; does not crack on drying; no clods; 25 years in cultivation; have used barnyard manure with good results; produces 25 bushels of corn, 2 tons of cane, or 100 bushels of potatoes; will not produce cotton, probably root rot.

3975. Lufkin fine sandy loam; 12″-24″; subsoil to 3974; brown to black clay loam.

4582. Subsoil to 4581; 18″-20″ to 30″-33″; light color; sandy; Henderson County; J. K. Camp's place, Chandler; no hard lumps, uniform, mixed ground and roots.

4586. Subsoil to 4585. 8″-20″; S. B. Blair's place, Marquez; light brownish red color; clay; lumps lighter than rest; hard; not uniform.

4587. 0″-6″; Denton County; T. B. Breeding's place, four and one-half miles S. E. Argyle; surface soil, poor upland, rolling; good drainage; light color; sandy; no good in wet seasons; stands drouth well; does not pack, crack, or wash dirt onto it; crumbles, washes; 30 years in cultivation; used spade full of manure to hill of corn once and got double the yield; fertilizer from Experiment Station used last year; crops are cotton and peanuts; produces one-fourth bale of cotton.

5095. Soil 1956 washed with strong HCl.

5701. Subsoil to 5700; 12″-24″; Fort Bend County; Adam J. Eulberg's place, Katy, Texas; yellowish gray; easy; uniform; no hard lumps.

6885. Subsoil to 6884; 12″-24″; Duval County; W. R. King's place, San Antonio; sandy; uniform; no hard lumps.

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SUMMARY AND CONCLUSIONS.

(1) As pointed out by Hartwell, sufficient evidence has not been presented to prove that manure affects the availability of rock phosphate to any decided extent.

(2) The average recovery of phosphoric acid on 25 pot experiments for several crops is 48.2±2.2 per cent. The average recovery in 22 experiments for the first crop is 30.6, compared with 47.3 per cent. for all the crops.

(3) The average quantity of phosphoric acid removed from manure in 22 experiments is 39.2 per cent., compared with 37.9 for acid phosphate in the same series. The manure has probably made some phosphoric acid of the soil available.

(4) The average recovery from acid phosphate when used with manure is less than for the acid phosphate used alone, perhaps due to the supply exceeding the needs of the plants in some of the tests.

(5) The average recovery of phosphoric acid from rock phosphate in 21 experiments is 9.1±1.1, compared with 43.9±2.3 for acid phosphate in the same experiment. Thus the phosphoric acid in rock phosphate had about one-fifth the availability of that in acid phosphate in these tests, in which several crops were grown.

(6) There are very decided variations in the value of rock phosphate in different soils.

(7) If the first crops grown are considered, and no others, phosphoric acid of acid phosphate has about six times the availability of that in rock phosphate.

(8) In 19 pot experiments the recovery of phosphoric acid from rock phosphate alone was 9.6 ± 1.3 per cent., and for rock phosphate with manure it was 8.6 ± 1.2 per cent. after correction for the phosphoric acid removed from the manure alone. The manure had no effect upon the assimilation of phosphoric acid from rock phosphate in these experiments.